NEW MICROWAVE NETWORK IDENTITIES FOR CAD MODELING

Don Neuf

RHG Division, M/A-COM
Deer Park, New York

ABSTRACT

Network identities are presented which allow one to model symmetric and homogenous two, three, or four coupled lines by using ideal 180 degree hybrids and separate uncoupled transmission lines representing each characteristic mode. These identities are helpful to intuitively understand the performance of these couplers as well as analyze them using commercially available CAD programs.

DESCRIPTION

Figure 1 shows an equivalent circuit of the "even" and "odd" modes of two coupled and symmetric lines as a simple network with 180 degree hybrids and separate uncoupled transmission lines. Note that the equivalent network has the same outputs that one would obtain by bisecting the original network and using Wheeler's even and odd mode analysis technique (1). The equivalent network is useful for understanding the behavior of coupled lines when the propagation velocities of each mode are unequal. For this case using matched generator and load impedances (equal to hybrid impedance) one can see from the model transmission paths that it is not possible to achieve the characteristic forward isolation of coupled lines, (S_{41}) unless two conditions are satisfied; the electrical path lengths (velocity) for the even and odd mode transmission lines are equal and the relative VSWR of the even and odd modes to the source impedance must be alike (i.e., $Z_o = Z_{oe} Z_{oo}$). Furthermore, when the transmission lines can support higher order modes, (microstrip) the even and odd portion of each mode must be added to the fundamental TEM mode by superposition using another similar network with appropriate ideal coupling networks.

Figure 2 shows another equivalent network for three symmetric coupled lines using the impedance conventions of Tripathi (2). This model is valid for the case where the three orthogonal mode impedances, (A, B, C,) each have different impedance components on the individual strips. This implies a particular set of even and odd mode voltages or incident scattering waves as shown. However, the individual modes must have the same velocities, and coupling coefficients.

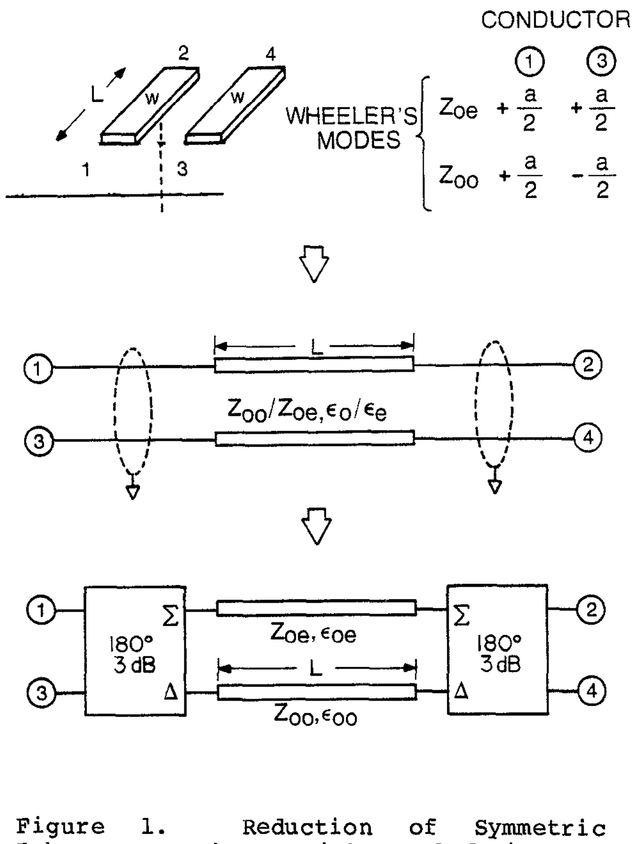

Figure 1. Reduction of Symmetric Inhomogenous 4 Port With Coupled Lines to Identical 4 Port Using Uncoupled Lines and Ideal Hybrids

Figure 3 shows an extension of this network description when there are four symmetric coupled lines or an 8-port network. The validity of the model can be verified by applying each of the four orthogonal modes to each of the input terminal pairs and expressing the output or reflected signals as a superposition of each eigenmode. This can be done by signal "flow-graph" paths. Note that the equivalent model has the same degree of symmetry as the physically coupled lines. This is necessary for the model to be invariant to which line is being excited. This, of course, also restricts the model to those conductor configurations which have equal strip impedances for any of the four eigenmodes. For the case of four coupled, equal width, planar transmission lines, (see Figure 4) there are still four unique modes, but the individual line admittances are not equal. We use the mode conventions of Jansen and Wiemer (3). Unlike the previous four wire line with greater symmetry, the even mode impedance of the middle two lines, (1, 3) in the planar model is higher than the outside two lines (5, 7). The first even eigenmode (IE) for the planar configuration would require greater incident voltage on the inner lines to produce reflected line voltages in the same ratio or eigenvector direction. The equivalent circuit for this network is not given, but rather a procedure for obtaining the asymmetric two line model is presented as an example.

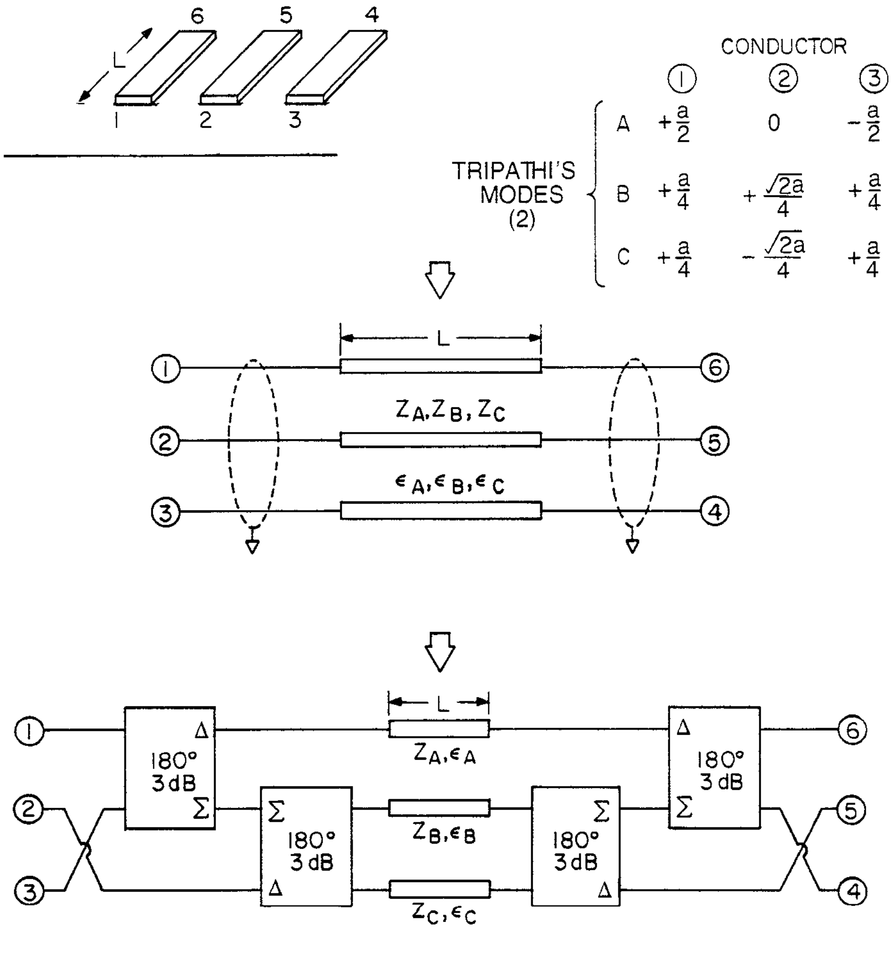

Figure 2. Reduction of Symmetric Homogenous 6 Port With coupled Lines to Identical 6 Port Using Uncoupled Lines and Ideal Hybrids

The circuit model for two asymmetric coupled strips was developed using the definitions of Tripathi (5). For this case the orthogonal or normal "c" & "π" eigenmodes have different voltage ratios when compared to the equal amplitude "even" and "odd" symmetric modes. The corresponding voltage ratios for the incident waves are given by R_c and R_π respectively. The corresponding characteristic admittance or impedance matrix for each mode is not diagonal and has four components. Therefore, four line admittances are needed in the equivalent circuit model. The mode velocity for each line in a "c" or "π" pair is the same for a given mode so only two beta values are required. Figure 5 shows the proposed circuit using Tripathi's relations.

SUMMARY

The proposed two, three, and four strip coupled to decoupled network identities have been found useful in computer modeling of complicated networks. In addition the flow-graph models help to intuitively understanding the network conditions for isolation etc. The models require prior knowledge of the mode propagation constants and characteristic impedances, but there are numerous techniques and available programs (4) to obtain these quantities.

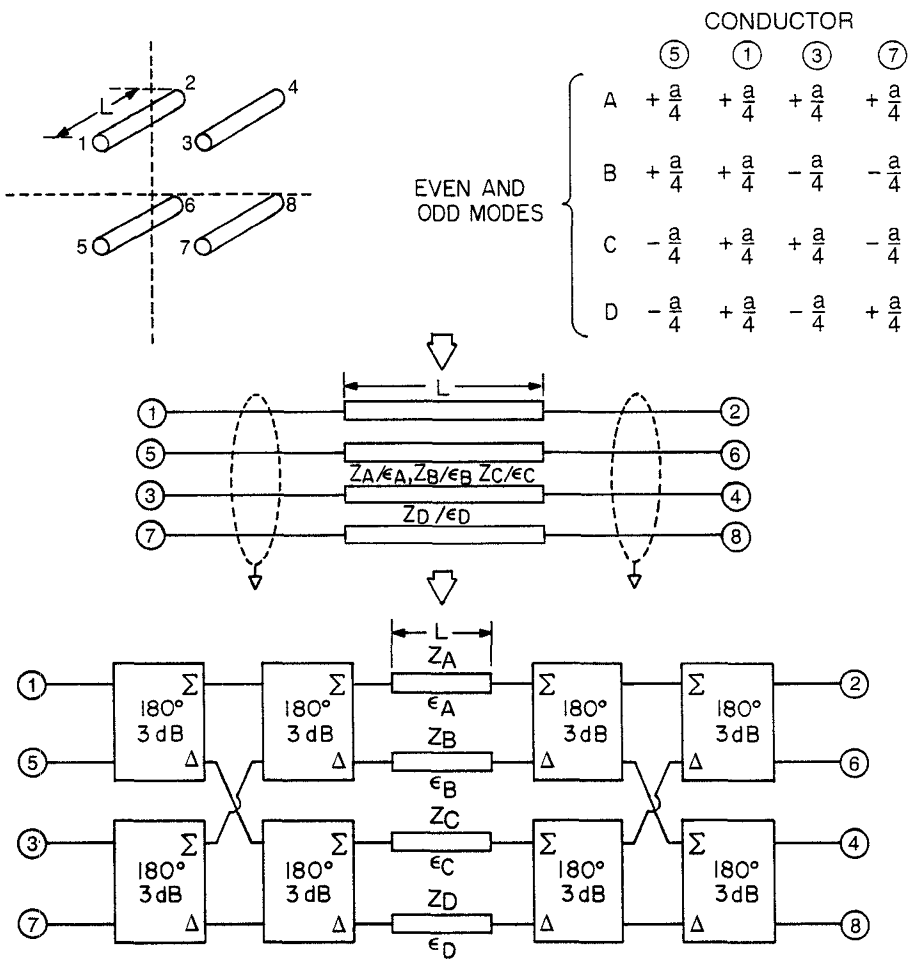

Figure 3. Reduction of Symmetric Homogenous 8 Port With Coupled Lines to Identical 8 Port Using Uncoupled Lines and Ideal Hybrids

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(5) V.K. Tripathi, "Asymmetric Coupled Transmission Lines In An Inhomogeneous Medium".

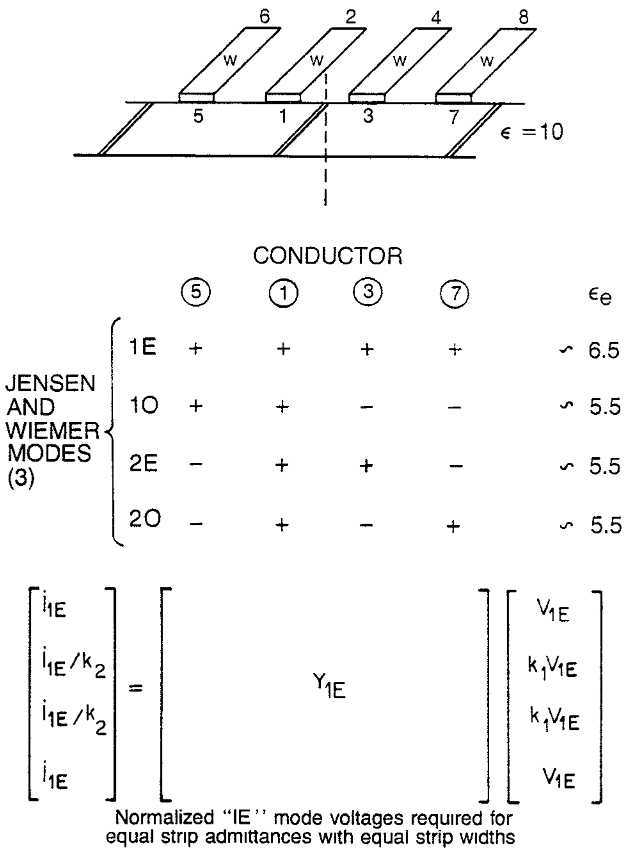

Figure 4. Mode Voltages For 4 Strip, Inhomogenous, Planar Symmetric, Coupled Lines and Y Matrix For One Eigenmode

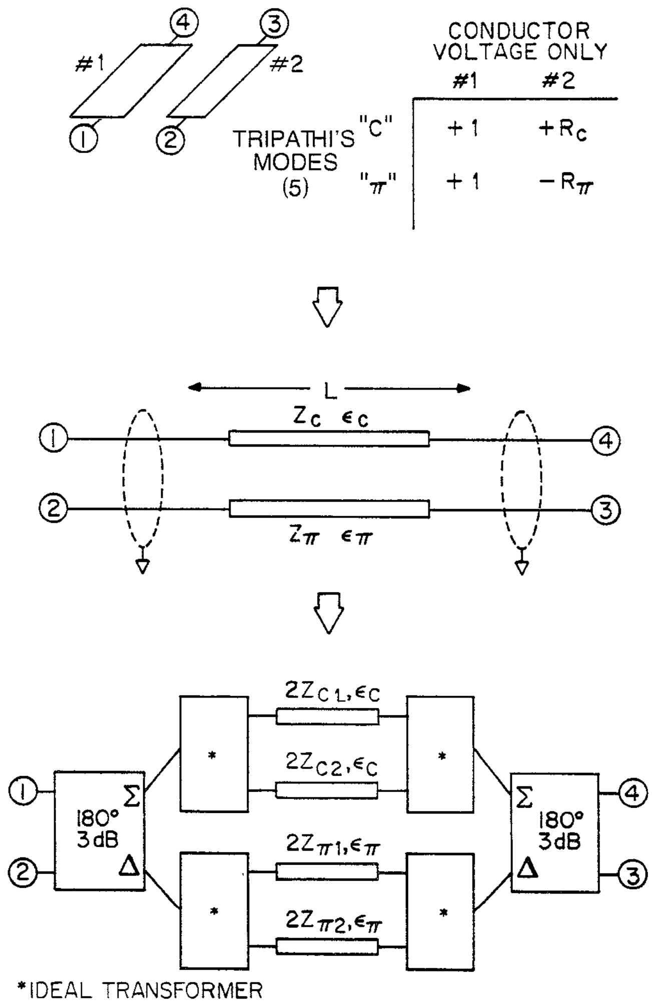

Figure 5. Reduction of Asymmetric, Homogenous 4 Port With Coupled Lines to Identical 4 Port Using Uncoupled Lines, Ideal Hybrids and Transformers